Progress Report

ATMOSPHERIC INFRARED SOUNDER

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for the period

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Submitted to Team Leader
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Algorithm Development Activity

The concept design documents for the preliminary version of the "microwave first-guess" algorithm and for research products (land snow/ice cover, sea ice cover, oceanic cloud liquid water, and precipitation) were delivered to JPL.

The surface emissivity model used in the "microwave first-guess" algorithm was revised to use fewer of the window channels to describe the surface. Then liquid water estimation might be improved. Since a number of changes have been made in the algorithm, the write test and flat test were reprocessed.

We were informed by R. Saunders at the U.K. Met Office that MHS instrument characteristics (Table 1) are somewhat different from those that we had been assuming. There are differences in frequencies between MHS and AMSU-B channels 17 and 20, which result in 8-10% greater atmospheric opacity at the MHS frequencies of those channels. The rapid transmittance algorithm and its coefficients for AMSU-A and MHS were revised to update the instrument descriptions and also to correct some minor bugs. The revised versions have been delivered to JPL; however they were apparently not in time to be included in the cloudy test software package, which uses the AMSU-B channel definitions.

Table 1. MHS channel characteristics (as of 3/15/94).

Channel no.	Center frequencies (GHz)	No. of passbands	Passband width (MHz)
16	89.0 ± 0.9	2	1000
17	157.0 ± 0.9	2	1000
18	183.31 ± 1.0	2	500
19	183.31 ± 3.0	2	1000
20	190.31	1	2000

Datasets for the cloudy test were received. In processing the cloudy test simulations, we discovered that the routine by which the brightness temperatures had been generated was not consistent in integration method with our retrieval algorithm. This resulted in temperature biases of several degrees. Conversations with JPL personnel indicated that the wrong routine had been used to generate brightness temperatures. It was agreed that JPL will redo the microwave brightness temperature files.

Figures 1 and 2 plot the means and standard deviations of brightness temperature errors from the rapid algorithm[1] for 26 channels and three profile types, at vertical incidence and at 60° from vertical, respectively. Channels 1-15 and 16-20 are the AMSU-A and -B channels. Channels numbered 21-26 are other channels not on the EOS platform. The comparison is with line-by-line calculations for temperature and moisture profiles from the TIGR ensemble. The first 100 profiles from each of the tropical, midlatitude and polar air mass groups were used.

The figures show that the errors are less than the instrument sensitivities for all channels, with the exception of some of the channel 1 tropical brightness temperatures. For channel 1, larger errors occur with the tropical profiles than the other types, whereas for channels 19 and 20, the larger errors occur for polar profiles. Both of these results can be understood as the effect of bandwidth on downward-propagating atmospheric emission that is reflected from the surface. This emission travels through a path of more than one atmosphere to reach a satellite receiver, but the effective opacity supplied by the rapid algorithm corresponds to frequency-averaged transmittance within the direct atmospheric path only. At the weak water line where channel 1 is located, this bandwidth effect is greater when the atmospheric emission is greater, whereas at the strong water line where channels 18-20 are located, the effect is noticeable only when low atmospheric moisture makes the atmosphere semi-transparent (which does not occur with channel 18). A separate opacity for downwelling emission could be added to the algorithm, but would require a change in the way the routine is used.

Cloud liquid water was not simulated in these comparisons. However, its absorption per unit mass of liquid water is a function only of frequency and temperature (under the restriction that droplet sizes are much smaller than the wavelength). Since the frequency of each channel is fixed, the only source of error in the rapid algorithm, relative to the "exact" formulation, would be the table interpolation with temperature. The approximation error in cloud opacity is estimated to be less than 1%.

Compaction of microwave radiometer measurements by neural networks was studied. With small numbers (1-2) of hidden nodes the neural network can reproduce a larger fraction of the total variance than the same number of empirical orthogonal functions in a Karhunen-Loeve transformation. The implication is that neural network retrievals may be superior due to their ability to capture *a priori* statistical information beyond second-order statistics.

Estimation of cloud-top altitudes with microwave measurements made from the ER-2 was reexamined. Earlier work[2] used an *ad-hoc* nonlinear estimation

[1] P.W. Rosenkranz, "A rapid transmittance algorithm for microwave sounding frequencies", International Geoscience and Remote Sensing Symposium, Pasadena, CA (August 8-12, 1994).

technique combined with a Karhunen-Loeve transformation. It appears that some small improvement over the earlier results can be obtained with a neural-network retrieval.[3] An example is shown in Figure 3.

A paper on the neural-network humidity profile algorithm described in previous progress reports was prepared.[4]

Aircraft-based Measurements During CAMEX

Preliminary results of the MIT Microwave Temperature Sounder from the TOGA-COARE and CAMEX flights were described at the Science Team meeting at NOAA. Figure 3 is a cloudtop altitude retrieval using the neural network. The swath width is narrow because it is referenced to 10-km altitude and because the algorithm was used only for the central portions of each scan, to minimize errors due to large angles of view, for which this algorithm has not yet been evaluated.

Figure 4 is a profile of brightness temperatures observed at eight channels near 118 GHz, looking up during ascent and descent of the ER-2. The up-looking data is being compared to theoretical calculations based on radiosonde measurements, with the objective of identifying systematic differences and relating them to parameters in the theoretical model. This work is still in progress.

A list of data availability from MTS during CAMEX is attached as Table 2.

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[2] A. J. Gasiewski and D. H. Staelin,"Statistical Precipitation Cell Parameter Estimation using Passive 118-GHz O_2 Observations", *J. Geophys. Res. 94*, 18367-18378 (1989).

[3] M. S. Spina, M. J. Schwartz, D H. Staelin, and A. J. Gasiewski, "Application of Multilayer Feedforward Neural Networks to Precipitation Cell-Top Altitude Estimation", International Geoscience and Remote Sensing Symposium, Pasadena, CA (August 8-12, 1994).

[4] C. R. Cabrera-Mercader and D. H. Staelin, "Passive Microwave Humidity Profile Retrievals Using Neural Networks", International Geoscience and Remote Sensing Symposium, Pasadena, CA (August 8-12, 1994).

Table 2

MTS CAMEX DATA SUMMARY
September/October, 1993 Wallops Is., VA

Flight	Date (take off)	Mode	MTS on (GMT)	MTS off (GMT)	Ch 0 freqs (GHz)	Ch 0 Freq. Step Rate	
93-163	09-11-93	up	17:51:47	19:13:12	1-8	1/ 11s	Pressure Lost in Pod
93-164	09-14-93	fail					Ferry Flight - Computer Disk Failure
93-165	09-15-93	Aborted					Pressure Lost
93-166	09-18-93	Aborted					Hydrollic Leak
93-167	09-25-93	up	16:09:16	18:23:30	1-8	1/ 11s	Engine Test. Mostly cloudy
93-168	09-26-93	down	18:51:46	23:40:50	1-5	1/ 5.5s	Small Convection over Ocean
93-169	09-29-93	up	00:52:47	04:57:41	1-8	1/ 5.5s	AIRS Flight
93-178	09-30-93	down	20:02:53	02:19:50	1-5	1/ 5.5s	DMSP Underflight
94-001	10-03-93	down	20:00:54	03:28:40	1-5	4/ 5.5s	Small Convection S. of Florida
94-002	10-05-93	down	15:54:13	23:40:00	1-5	4/ 5.5s	Strong Convection in Florida
94-003	10-07-93	up	13:57:55	20:09:04	1-8	4/ 5.5s	Ferry Flight

Channel 0 Frequencies (GHz)

1	2	3	4	5	6	7	8
52.800	52.952	53.310	53.480	53.596	54.940*	55.105*	55.500*

Channel 0 was scanned through either five or eight frequencies, as indicated.

*The top three scanned frequencies failed above 58K' on ascent, except on flight 93-163

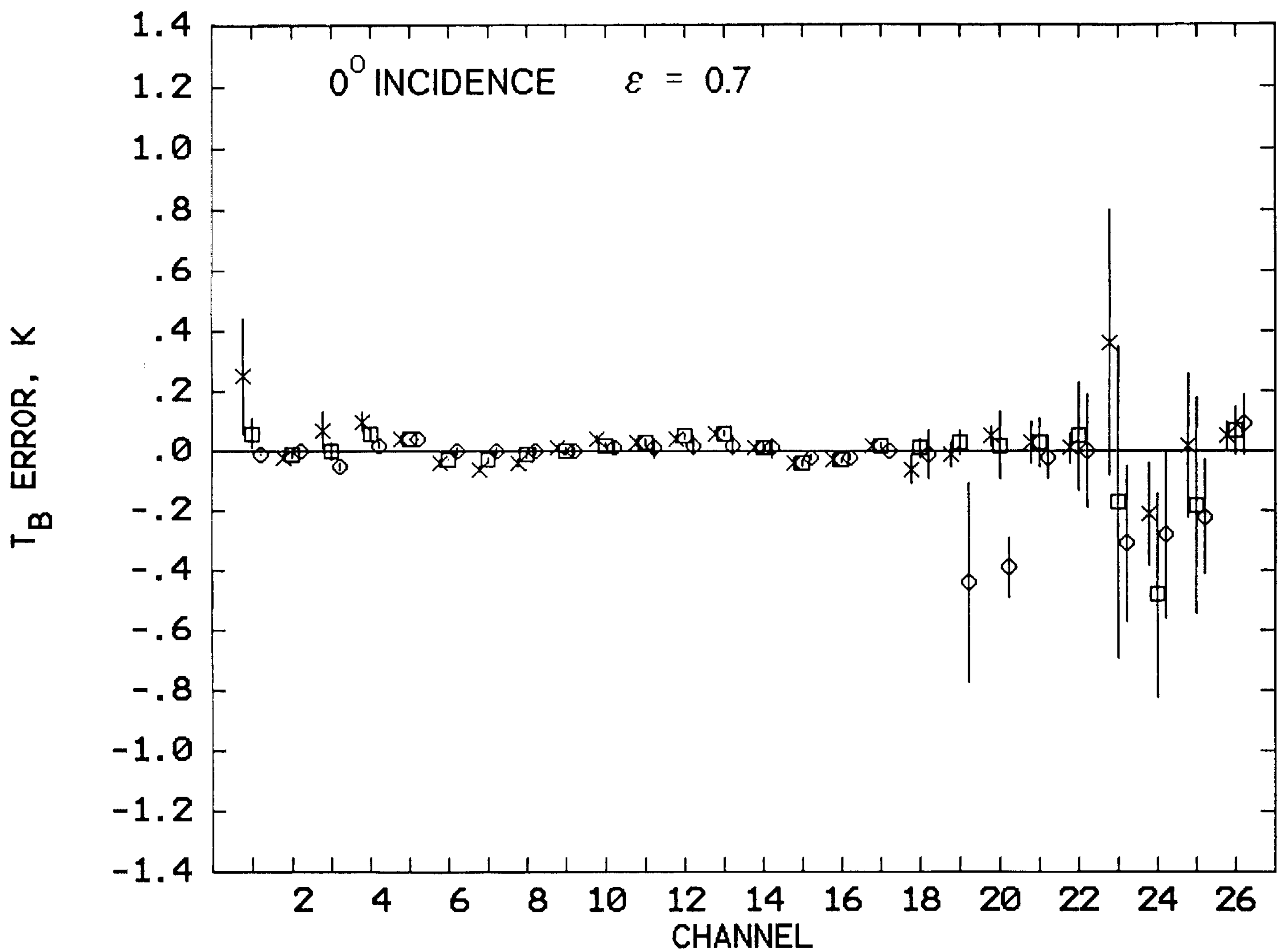


Figure 1. Brightness temperature errors (rapid algorithm minus line-by-line algorithm) at vertical incidence and emissivity = 0.7: X - mean error for tropical profiles; square - mean error for midlatitude profiles; circle - mean error for polar profiles. Vertical lines indicate ±1 standard deviation.

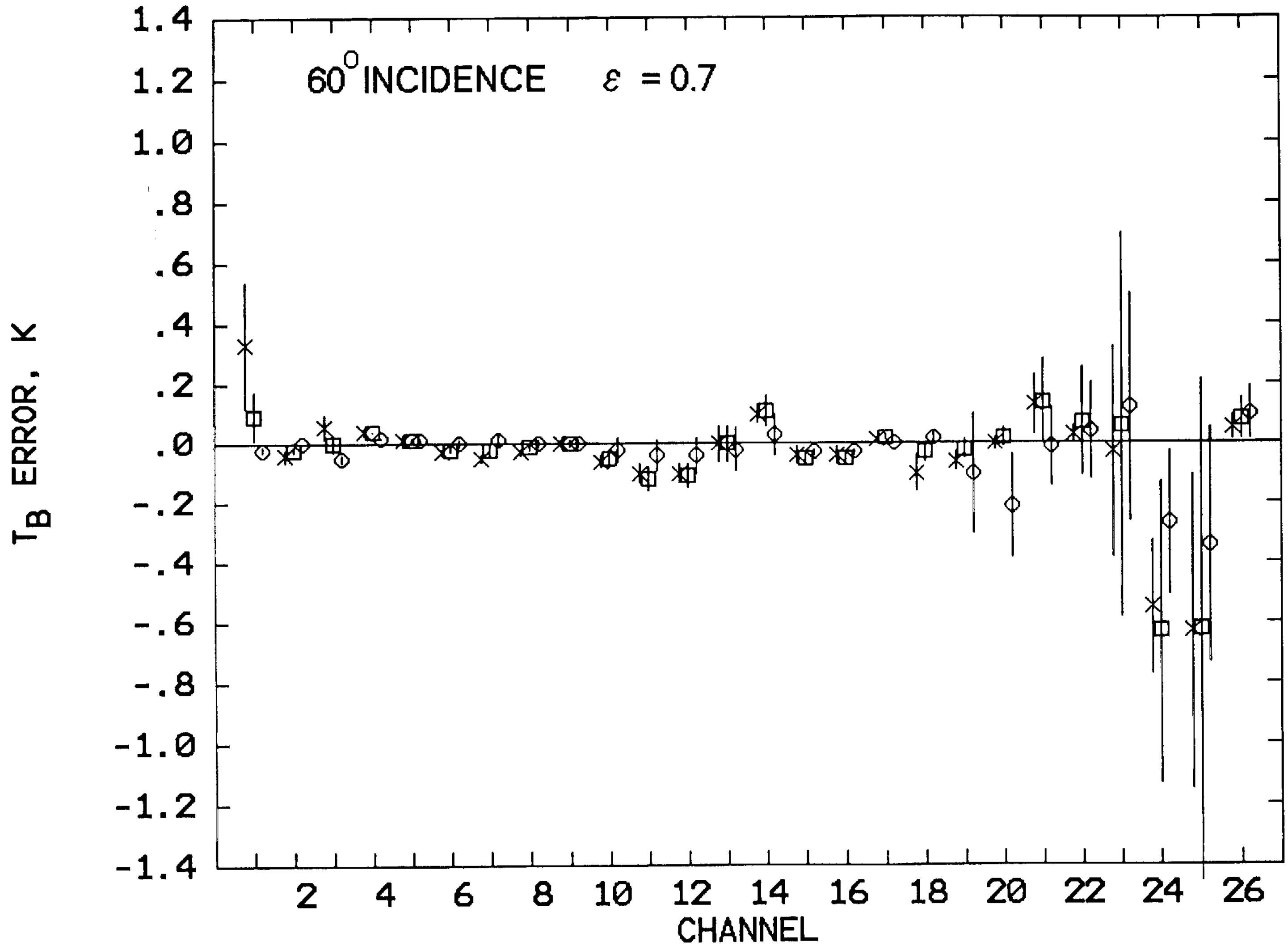
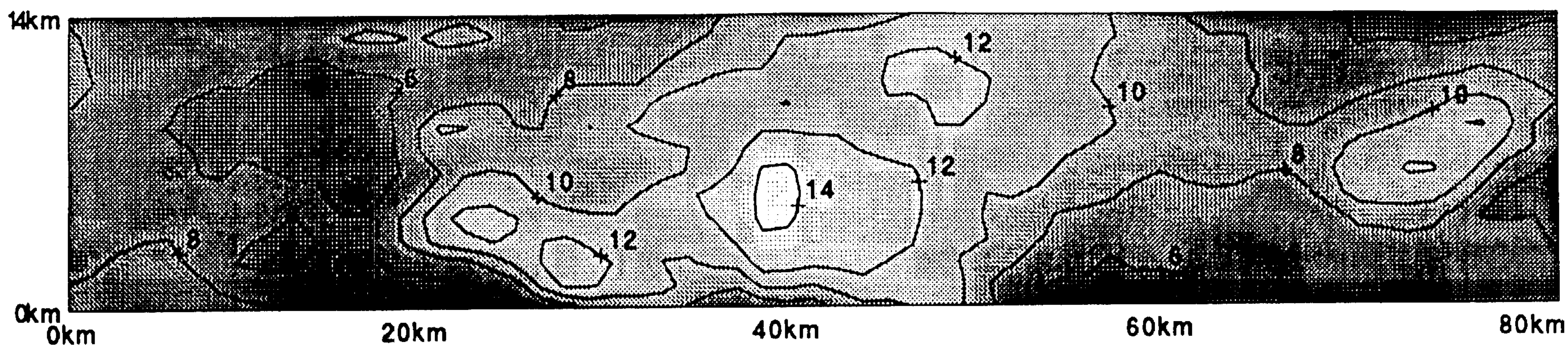
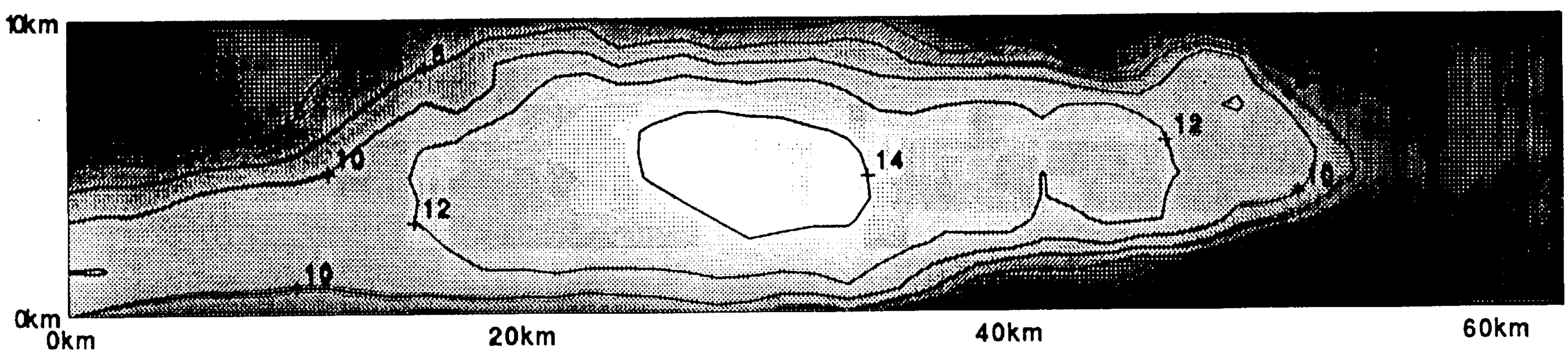


Figure 2. As in Fig. 1, but at 60° incidence.

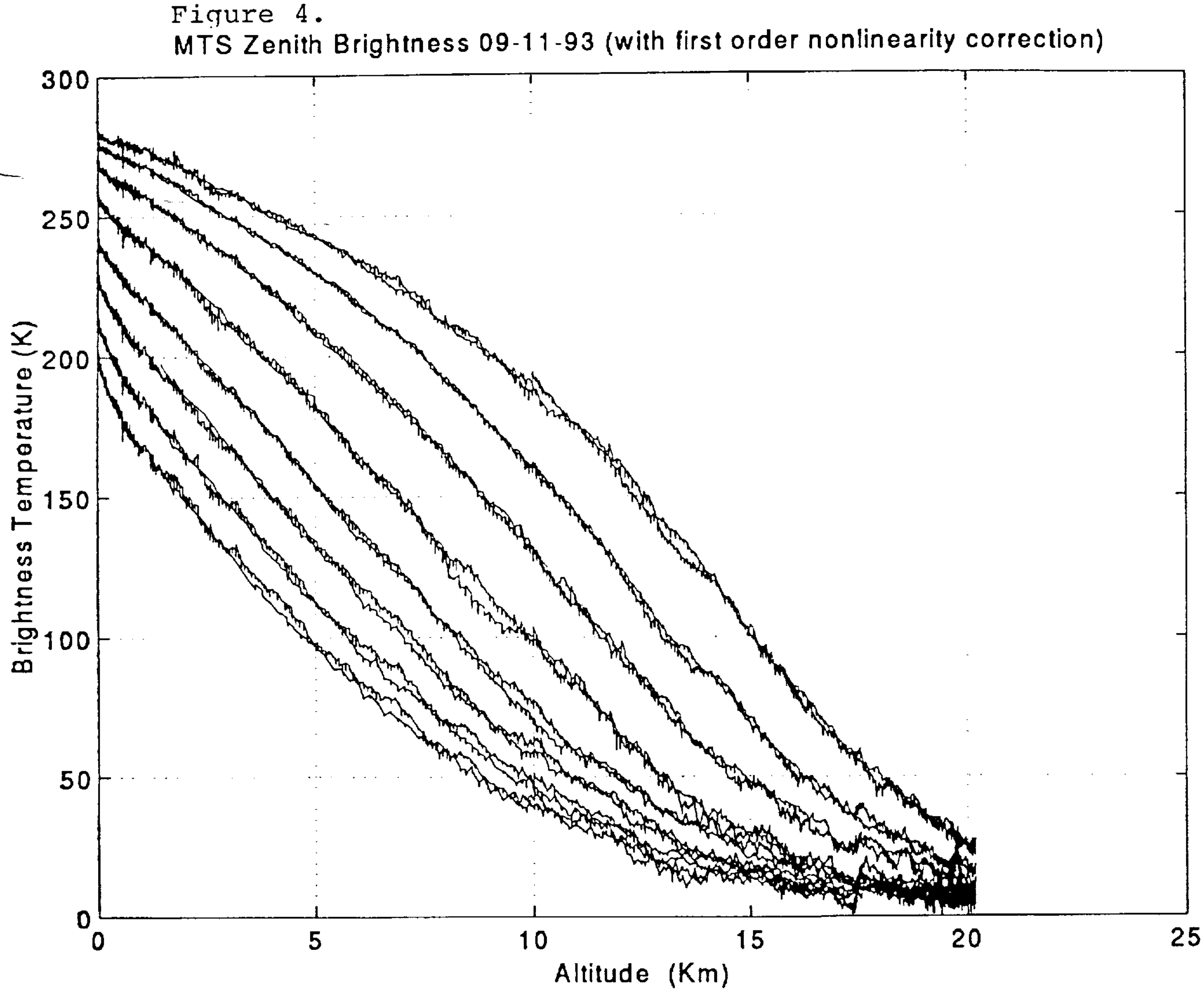




Cloud-Top Altitudes (km) Retrieved From MTS 10-05-93 Data Using a Feedforward Neural Network

Figure 3

Figure 4.


MTS Zenith Brightness 09-11-93 (with first order nonlinearity correction)
Brightness Temperature (K)
Altitude (Km)
300
250
200
150
100
50
0
0
5
10
15
20
25

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15. Supplementary Notes

16. Abstract

This report summarizes the activities of AIRS Team Members P. W. Rosenkranz and D. H. Staelin during the first half of 1994.

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